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Perspectives for project-based STE(A)M activities in early childhood education

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Abstract

The purpose of this study is to investigate project-based and problem-based instruction STE(A)M activities for children aged 4-6 years old in STE(A)M Preschool Classroom Environments. A French film ("Le balloon rouge", 1956) was the occasion for the creation of an authentic communication framework that encouraged and supported the planning and the development of contextualized STE(A)M activities based on educational robotics and computational thinking. These were referred mainly to mathematical concepts through a problem-based solving process. Students using several materials and strategies tried and attempted to sculpt physical distances among nations and people using digital tools and in particular using the Bee-Bot Robot. The results showed that pre-schoolers enjoyed the use of digital tools and their possibilities corresponding to directional codes. They used mathematical concepts and many non-standard (arbitrary) or conventional measurement units as tools to solve the problem of sculpting the distances. Furthermore, under the appropriate guidance and into an educational robotic context, they managed to make the robot move in a correct and appropriate way after mane repetitions and utilizing the opportunity to construct and reflect on new learning trajectories.

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Introduction

In recent years new perspectives and advances in educational and scientific community and research have been highlighted. These perspectives have identified computational thinking practices, educational robotics activities and technological literacy as content-specific learning outcomes that students are developing in new learning environments (Bers et al., 2018; Bellanca, & Brandt, 2010). Educational research emphasizes the importance of developing skills and abilities associated with this pedagogical shift towards technology integration, including collaborative problem-solving, design and inquiry cycles, computational thinking, and STEM identity development (Bers et al., 2013; Lippard et al., 2017; Sullivan & Heffernan, 2016). In this context, developing STEM (Science, Technology, Engineering, Mathematics) competencies is a global priority for all levels of education as well as the scientific community. However, in early childhood education the development of STEM competencies is more recent. Specifically, project-based and problem-based instruction STEM activities are not yet very widespread in preschool education. Furthermore, the use of educational robotics and computational thinking as a pedagogical method and resource for STEM activities is a really current research topic (Salvatierra & Cabello, 2022; Sullivan & Heffernan, 2016) which remains unexplored in preschool education.

Literature Review

What is STEM or STE(A)M

STEM is an educational resource and approach designed to combine Science, Technology, Engineering and Mathematics (Bybee, 2010; Lippard et al., 2017) for performing activities with high cognitive demands at all levels of education. Last years, there is also a recent successor, STE(A)M (Buchter et al., 2017; Sousa & Pilecki, 2013). This term incorporates the Arts (Science, Technology, Engineering, Arts and Mathematics). STE(A)M as an educational approach and resource integrating arts into daily science, technology, engineering, and math (STEM) instruction is designed to encourage discussions and problem-solving among students, developing practical skills and collaborations (Sousa & Pilecki, 2013). Science, technology, engineering, and

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mathematics (STEM) or Science, Technology, Engineering, Arts and Mathematics STE(A)M experiences during the early years provide young learners with a critical foundation for future learning and development (Buchter et al., 2017; Mayerick, 2011; Tank et al., 2018; Van der Graaf et al., 2016) and facilitate connections and learning across project-based activities. In this paper we are going to use the term STE(A)M for these experiences as the project activities we will describe integrated into a communication framework involve important aspects of art.

STE(A)M education is distinguished from traditional science and math education because of its blended learning environment (Bishop-Josef et al., 2016). This environment can show students how scientific methods can be applied to everyday life and incorporate practical skills, collaborations (Bishop-Josef et al., 2016; Buchter et al., 2017; Sousa & Pilecki, 2013;) computational thinking, and coding competencies. The experiences which are provided towards this blended learning environment are focusing on standards-based structured inquiry-based and real-world problem-based learning activities connecting all five of the STE(A)M subjects.

That's why STE(A)M education, today more than ever, is really crucial to meet the needs of a changing world. As STE(A)M education is an attempt to evolve from the tutor-centered approach into a teaching method that involves problem solving, creative initiative, research and hands-on activities (Bishop-Josef et al., 2016; Papadakis et al., 2022;) students experience unprecedented learning experiences. In this context, STE(A)M offers a chance for children to develop their abilities encouraging them to answer questions and get involved with fun activities based on science, mathematics, engineering, arts and technology. It is truly impressive how the children react to this method, as they seem to find it more interesting and appealing. By applying STE(A)M activities through various projects, students learn to process facts, focus on solving problems, gain abilities fitting to global education framework, develop critical, computational thinking and coding competencies working in a teamwork context (Bequette & Bequette, 2012; Kelley & Knowles, 2016).

Why STE(A)M education is important in early childhood education

In recent years there has been a great deal of debate and it tends to be generally accepted that STE(A)M activities are considered crucial to students' future success (Fayer et al., 2017). However, there is limited research examining the use of project-based STEM or STE(A)M integration within the early childhood classroom (Bers et al., 2018).

The question that arises and calls for an answer is why STE(A)M constitute an important resource for early childhood education (Dubosarsky et al., 2018; Hadzigeorgiou, 2016; Papadakis et al., 2022). Commonly reported reasons for the importance of early childhood education STE(A)M education are the development of skills, knowledge, and competencies through project-based or problem-based instruction STEM activities. Specifically, students have the opportunity to develop skills such as collaboration, communication, creativity, critical and computational thinking, intercultural career and learning understanding and empowerment (7Cs Skills of the 21st century) (e.g., Tank et al., 2018; Thibaut et al., 2018; Van der Graaf et al., 2016). In the same context, and as educators give opportunities to their students to strengthen these skills, abilities like socialization, problem-solving, experimentation, programming, coding, and language/literacy cultivation (Fayer et al., 2017; Larkin & Lowrie, 2023; Wood et al., 2016) are cultivated. Young children are naturally curious about their world (Piaget & Inhelder, 1928) and actively participate in their environment by defining problems, manipulating them, building and testing prototypes, applying mathematical and scientific concepts, and sharing solutions with friends, teachers and family (Buchter et al., 2017). Natural development of scientific inquiry, observation, measurement, prediction, inference, and communication skills (Ministry of Education/P. I, 2003) are increased with sophistication as children participate at project-based STE(A)M activities (Piaget & Inhelder, 1928). In conclusion, kindergarten teachers, utilizing children's interest for learning, have the opportunity to prepare their students for a successful and fulfilling future through authentic communicational contexts and

STE(A)M projects (Campbell & Speldewinde, 2022).

Although STE(A)M is an educational methodology that is absent from the older Greek curricula for kindergarten (Ministry of Education/P. I, 2003), nevertheless in the Greek educational system and in the pilot applied new curricula for preschool education (Ministry of Education/P. I, 2021) it is obvious the introduction of both engineering and educational robotics as resources for new educational fields. The new syllabus introduces these innovative concepts for preschool education which are obviously connected to methodologies based on to project or/and problem-solving STE(A)M activities. These activities developed to promote knowledge and skills which were lacking in older programs and which are necessary for a human being future, as children could have the chance to actively involved in analytical, critical and synthetic thinking activities (Wood et al., 2016).

Project-based STE(A)M interdisciplinary activities

STE(A)M activities implemented in preschool classrooms are interdisciplinary activities, as well as experiments and exploration of materials. In a such educational setting preschool teachers aim to create the appropriate educational conditions for development of creativity, innovation, spirit of cooperation, and technological knowledge (Sullivan et al., 2017). They also promote the strength of school knowledge performance that concerns the better and more efficient understanding of mathematics, natural sciences and new technologies, with special emphasis on the introduction of engineering, coding and educational robotics in preschool classrooms (Campbell & Speldewinde, 2022; Guzey et al., 2017; Luehmann, 2009; Papadakis et al., 2022; Sullivan, 2008).

Many preschool teachers are trying to develop students' positive STE(A)M perceptions by using authentic communication and project-based or problem-solving instructions. The use of these contexts can enhance students' motivation for learning and improve their interest, achievement, and persistence (Papadakis et al., 2022). Furthermore, opportunities to participate in authentic STE(A)M learning experiences are really important, as students engage in authentic learning experiences in a collaborative group setting by exchanging views and perspectives. For these reasons, a need exists for informal learning environments to provide students with meaningful exposure to a STE(A)M community in which to participate, practice, and belong (O'Connell et al., 2017).

Especially, the learning area of Mathematics is considered a crucial subject matter for early childhood education as pre-schoolers use mathematical ideas in everyday life and develop mathematical knowledge (Clements & Sarama, 2009, 2011; Larkin & Lowrie, 2023; Papadakis et al., 2022; Tank et al., 2018) in authentic learning experiences. Compared to literacy and social emotional development, early math concepts were also one of the most powerful predictors of future learning and academic success. This perspective makes mathematics a prime factor for interventions to support multiple areas of learning (Day-Hess & Clements, 2017; Larkin & Lowrie, 2023; McClure et al., 2017; Papadakis et al., 2022;).

In the last few years, preschool education has offered an enriched learning environment that allows the involvement of pre-schoolers in mathematical activities. Specifically, pre-schoolers are not "taught" mathematics in the traditional sense of the term (Lavidas et al., 2022). Instead, they develop mathematical thinking, cultivate important skills and explore unexplored learning areas through authentic everyday activities and experiences. These interdisciplinary activities give students the opportunity to explore patterns, shapes, numbers, and spatial concepts (Lavidas et al., 2022). In the same context, game-oriented activities, routines, utilizing situations from everyday life, occasional or current events, and investigations (work plans, little research, problems to be solved) support mathematical processes (Larkin & Lowrie, 2023; Lavidas et al., 2022) and help students to become familiar with mathematical concepts. The National Council of Teachers of Mathematics (2000) presented five mathematical areas: a) Numbers and operations, b) Algebra, c) Geometry d) Measurements, and e) Data Analysis and Probability. Considering

these mathematical contents preschool teachers as facilitators (Kucer, 2009) have an essential role in choosing which of them are the most crucial and necessary for their students. Furthermore, they could choose the methodology, the resources, the interdisciplinary activities and the supporting materials and tools to support, encourage, and promote the cultivation of children's math concepts (Lavidas et al., 2022).

In the same context, considering the role of technology (such as programmable toys) which facilitates children's familiarization with early mathematical concept, preschool teachers have the chance to improve students' problem-solving and spatial orientation abilities (Clements & Sarama, 2002; Sullivan et al., 2017). Especially for the use of the robot Bee-Bot, as Komis, Romero and Misirli (2017) referred the educational robotics activities are aligned to the development of the 21st century skills such as collaboration, problem solving, creativity, critical thinking and computational thinking. These skills and abilities are cultivated and strengthened as students are actively engaged in authentic learning experiences. Specifically, students tested several solutions to solve problems by designing paths for moving Bee-Bot to multiple directions. Each solution included directions, instructions, orders and spatial orientation and were designed and represented by pre-schoolers using the cards commands (Misirli et al., 2019). Thus, the path-programme with specific directions and instructions is executed by Bee-Bot could reinforce pre-schoolers design of directions, choice of commands, and validation of the given solution. Students have the opportunity to construct and reflect on new learning trajectories (Misirli et al., 2019) as they themselves discover and design new perspectives of learning, coding and computational thinking.

In this context, the project-based STEM activities which are presented in this paper are focused at mathematics, coding, computational thinking, and engineering. However, although the emphasis is placed on the development of these abilities, simultaneously significant importance is given to the expression of students' creativity and the stimulation of their imagination through art activities (STEAM). In the same way, through discussions, dialogues, the formulation of hypotheses, predictions, the use of elementary argumentation to explain their choices, young students practiced and developed their language and communication skills and abilities. All these project-based STE(A)M activities arising from an authentic communicative context and focusing on solving an existing problem cultivate pre-schoolers coding, mathematical, technical, mechanical and computational thinking and skills.

Method

Research design

This paper refers to a case study which concerns a "good practice" that took place in the second semester of the school year 2021-2022 in a Greek kindergarten, and especially on a Greek island of Cyclades, Syros. A film was the occasion for the creation of an authentic communication framework that encouraged and supported the planning and the development of project-based STE(A)M activities. These were referred mainly at mathematical concepts through a problem-based solving process. The fourteen (14) participating pre-schoolers (9 girls and 5 boys) with the support and guidance of their teacher participated actively and with undiminished interest in all interdisciplinary activities.

The project-based STE(A)M activities aimed to a) the creation of appropriate educational conditions for expression of creativity and innovation, b) the development of applications of natural sciences and new technologies, with special emphasis on its methods and applications, c) the introduction of engineering and technological knowledge, d) the introduction of computational thinking and coding in education process with an emphasis on educational robotics, e) the strengthening of school knowledge performance that concerns the better and more efficient understanding of practical courses – physics, mathematics, IT, f) the activation of students' interest by meaningful and authentic activities and the active participation and involvement into these of all the students and not only those who are interested and engaged in the fields of new technologies and educational robotics, f) the collaboration practices between teachers and students and between the students among themselves, g) design a safe path for students to

self-activity, self-learning, maturity and knowledge, h) to help and encourage students to be competent and confident STE(A)M learners from an early age, i) the interdisciplinary approach to knowledge, and j) the cultivation of the concepts of democracy, human rights, equality, justice, and freedom.
STE(A)M project-based instructions arising from an authentic communicative context provided the right environment for the implementation of interdisciplinary and teamwork activities in early childhood education.

Study group

Fourteen (14) pre-schoolers, 9 girls and 5 boys, participated at this study after the written permission of their parents. Specifically, the teacher asked for parents' permission for their children's actively participation in all actions of this project.

Data collection tools and process
Research-project design

The authentic educational and communication context which constitutes the framework for project-based activities emergent by the screening of the French (short, 34 minutes) film "The Red Balloon" (Le balloon rouge, 1956) (image 1).

The Red Balloon (The Red Balloon) is an Academy Award-winning screenplay "fantasy" film, shot in 1956 by French director Albert Lamorisse. Set in the districts of Paris it's about a young cheerless Parisian boy who finds a red balloon one day on his way to school. The story refers to the connection between the Red Balloon and the little boy and how it affects his life. Both boy and balloon immediately became firm friends.

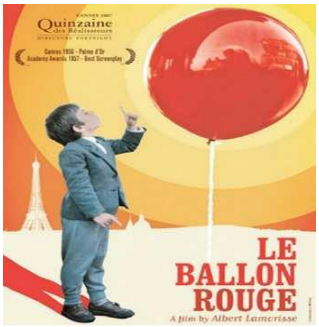


Image 1. The French (short) film 'Le balloon rouge', 1956

The bright red balloon, which has a will of its own, symbolizes hero's imagination and the innocence of his age. The director does not reveal anything more about the child and his life. His parents are nowhere to be found in the film, he lives with an old lady who may or may not be his grandmother, we don't know anything about his background or if he actually has any friends. By finding the balloon, the little child essentially acquires a sense of responsibility and faces his adulthood. The balloon begins to follow the boy, never straying far from him, and at times floating outside his bedroom window, as his grandmother/ guardian will not allow it in their apartment. The film explores important topics and phenomena that preoccupy preschool children in a latent way. Specifically, it explores and touches on themes, such as bullying, alienation and loneliness, conflicts between children, etc. Using only music and minimal dialogue, the film "put" students inside the imagination of the child, who could be any child of that time.

The film utilizing as the main vehicle childhood's imagination invites us "dumbly" to follow him. In the film there are strong symbolisms, the most important of which is the hero's effort to protect his friend, the red balloon. A symbolism that becomes even more intense at the end, when the balloon is violently destroyed by a 'gang' of children circulating in the neighbourhoods of Paris at that time. An unexpected optimistic ending conveys positive messages and perspectives to children's souls by stimulating children's imaginations. All the balloons of Paris being released and coming to carry the child high away from all this violent situation. Within such a non-realistic but ideal environment, the balloon easily transforms from a simple child's toy and company into an image symbol of freedom and perspective for a successful and fulfilling future.

This film as an authentic communication framework utilized by pre-schoolers' teacher and initially Greek students "became friends" with the hero of the film, developing a special relationship. The relationship between the hero of the film and pre-schoolers was artificially strengthened by their teacher to encourage the continuity in the culture, the traditions and the continuity of learning experiences at home and in kindergarten through cultural exchanges,

students' emotional and social skills and cultivation of human value system. Students showed interest in solving the realistic problem of reducing the physical distance between them and their cinematic friend by leveraging of digital and computational tools, mechanical and engineering materials/tools and robots. Simultaneously, the friendship with the hero and the emergent problem which the children had to solve operated as an authentic context for the cultivation and the development of cooperations, critical, computational, and mathematical thinking, for students' practice and familiarity with coding, engineering, and several mechanical and technical skills.

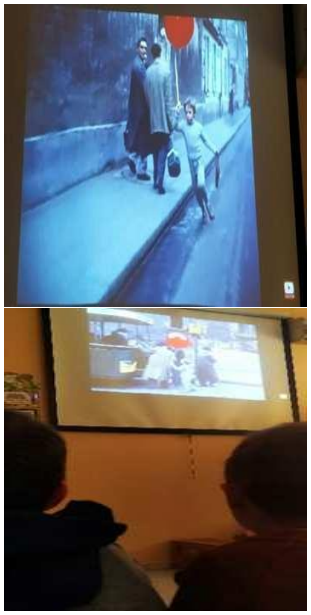
Materials and methods of the STE(A)M project-based activities

The fourteen (14) participating pre-schoolers with the support, strengthen and guidance of their teacher participated actively and with undiminished interest in project-based activities which organized and applied in the early childhood education during almost 6 months, such as: a) discussion about the film's hero (pre-schoolers themselves named "François" through a voting process) and his life in Paris, b) language activities with the initial letter of the hero, Paris, with French words, writing and exchanging letters, electronic messages with the little protagonist of the film, c) virtual tour of Paris and comparison of the city in its current appearance with the Paris depicted in the film (google maps, google earth), d) comparison of the hero's lifestyle in Paris with the life of the young students in Greece (quality of life, school time, interpersonal relations, friendships, family time, etc.), e) references to common cultural elements, human rights and democracy in these two places, f) mathematical thinking activities, g) computational and coding activities, h) engineering and mechanical activities.

A website created through which activities (video, images, audio, interactive content) were promoted with the utilization of digital tools (internet, e-mail, software, platforms, google map, google, etc.) to support pre-schoolers and their parents in their learning process.

Description of the STE(A)M project-based activities

The screening of the French (short) film "The Red Balloon" (Le balloon rouge, 1956) was the occasion as an authentic communication framework (images 2, 3) of the design and applying of many project-based activities in an early childhood education setting.



Images 2 & 3. Screening of the film "The Red Balloon"

During the project activities for literacy, oral and written language, creation, history, geography, culture, etc. were carried out. A special emphasis was given to STE(A)M activities and especially in the area of Mathematics. Pre-schoolers formulated questions while solving the problem of reducing, sculpting and bridging the distance between the two countries, namely Greece which is their own place of residence and France which is the place of residence of their film friend, François. Students also expressed many thoughts and suggestions about the way and means of transportation to reduce the physical distance that separates them from their beloved friend. Kindergarten teacher and Image students used mathematic concepts and many non-standard (arbitrary) or conventional measurement units as a tool to solve the problem of sculpting the distances (image 4).

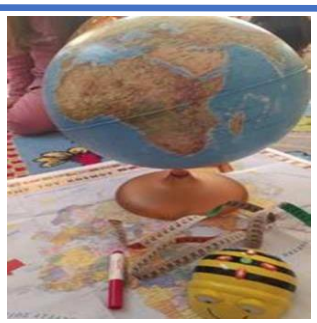
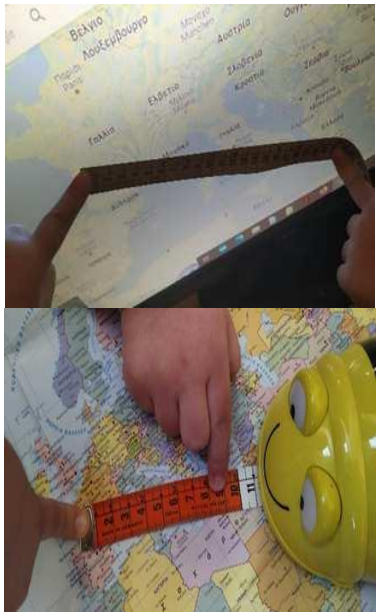


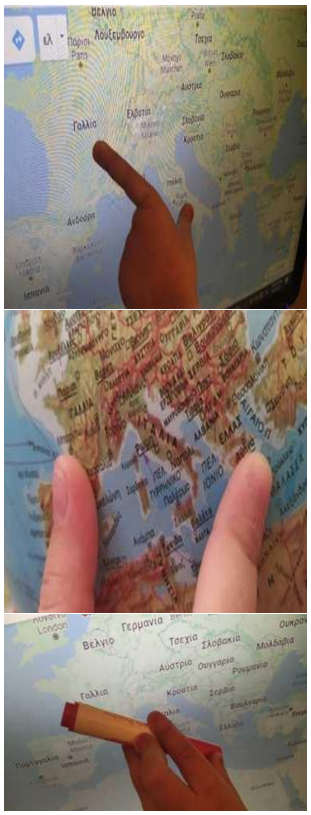
Image 4. Materials of project-based STE(A)M activities

Students wanted to mentally travel to the city where their friend Francois lives, Paris. For this reason, they measured distances with conventional units of measurement (meter, ruler, etc.) (images 5 & 6).



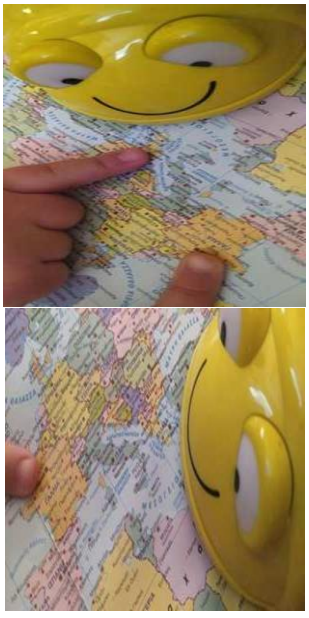
Images 5 & 6. Measurement with conventional units

Specifically, utilizing online software (e.g., google map and google earth) they located Paris on the map. Then they switched to the globe and using the ruler as a conventional unit of measurement they measured the distance from where they live to Paris. Students did measurements of lengths and distances, comparisons, calculations, numbering, etc. Dialogic discussion and use of argumentation was developed regarding calculations and comparisons of measurements. Also, by using non-standard (arbitrary) units of measurement of various objects students dealt with various concepts of Geometry, Algebra, Counting, and Measurement (palm, fingers, span of hand, markers, pencils, etc.). Specifically, they measured the distance from where they live to Paris (images 7, 8 & 9).



Images 7, 8 & 9. Measurement with non-standard units

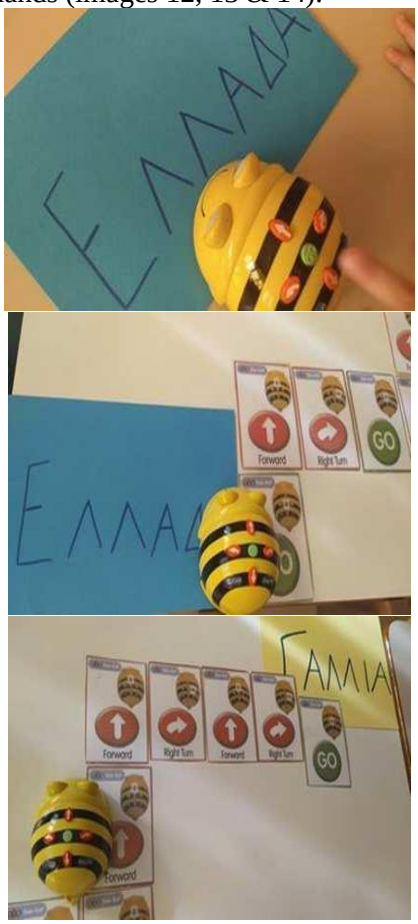
Using the Bee-Bot Robot students utilized their possibilities corresponding to directional codes, after first directing it to locate Greece and France on the map (images 10 & 11).



Images 10 & 11. Bee-Bot robot locate Greece and France at the map

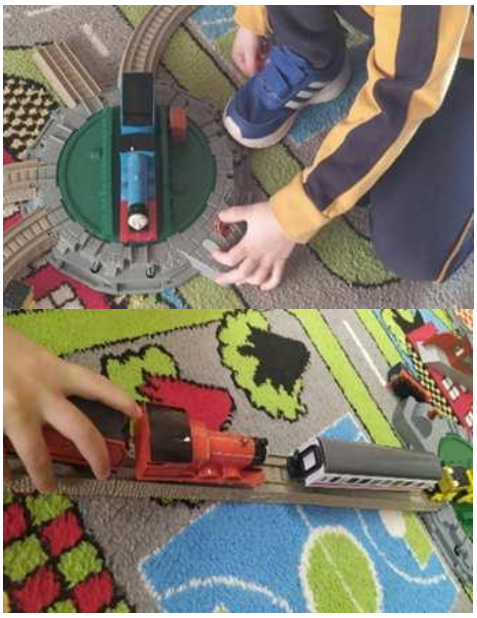
Furthermore, under the appropriate guidance, they managed to make the robot move in a correct and appropriate way. They followed some rules and directions to "drive" Bee-Bot Robot from Greece to France and back. Using the global map students visited their friend François by the company and the help of Bee-Bot Robot.

Pre-schoolers with great enthusiasm, interest and joy led the little rodot bee on various routes following directions, routes and tracing paths that they had already drawn on a paper using conventional and non-conventional (arbitrary) units of measurement of length and the cards commands (images 12, 13 & 14).



Images 12, 13 & 14. Bee-Bot follows pre-schoolers' directions-cards commands

Pre-schoolers gave commands to the little robot while they operated the direction keys and commands themselves. They changed paths when they realized their mistakes and corrected them. Pre-schoolers in small working groups studied and decided their movements to direct the little bee on the European map to be driven from Greece to Paris. Furthermore, pre-schoolers became architects, builders, civil engineers laying out roads for planes, trains and also for the robot Bee-Bot (images 15, 16).

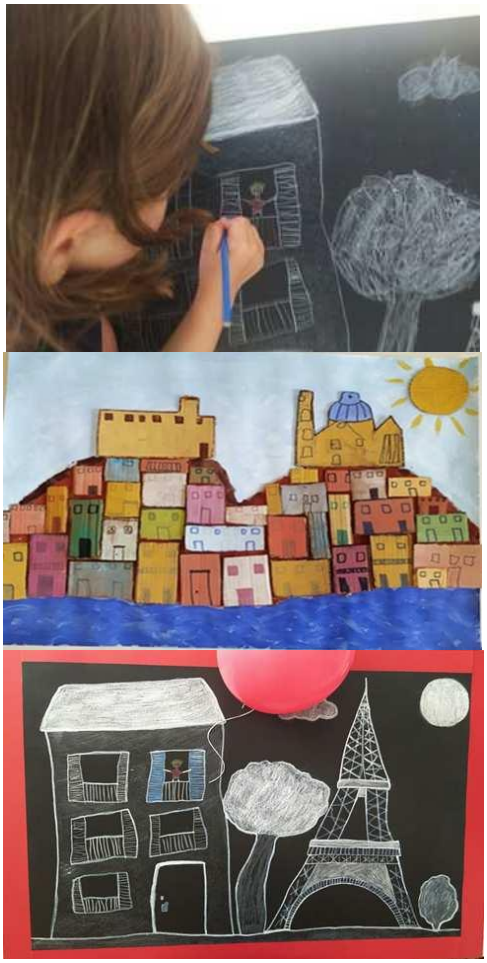


Images 15 & 16. 'Driving from Greece to France'

Students also constructive buildings, villages, cities and islands, using building and construction material (image 17 & 18). Especially, they constructed Eiffel Tower (image 18) in many ways because they found it very attractive and impressive.

Images 17 & 18. Constructions by using several materials

Furthermore, they imprinted their island (Syros) (image 19) and Francois's place (Paris), in various ways (image 20), focusing mainly on the Eiffel Tower (image 21). Students with a vehicle of imagination and creativity they reduced the natural distances 'viviting' and familiarizing with European cultural elements.



Images 19, 20 & 21. Students' fantasy and creativity for STE(A)M activities

Findings

The project-based STE(A)M activities which emerged from an authentic communication context and implemented in a pre-school classroom are the verification of the need to carry out meaningful activities for pre-schoolers. Young students need to actively participate in STE(A)M activities that emergent and based on their true and meaningful interests. In this way, these project-based activities seemed to stimulate students' interest and active participation even more because of their specific context and framework. As students showed interest and tried to solve the problem of reducing distances they used and dealt with digital and computational tools, mechanical and engineering materials/tools and robots.

The authentic educational and communication context functioned as a basis for STE(A)M activities promoted knowledge and skills, which are necessary for a human being future and refer to the recent Greek curriculum for kindergarten (Ministry of Education/P.I., 2021). Pre-schoolers with the support and reinforcement of their teacher utilized opportunities to cultivate and strength skills as technological knowledge, computational and critical thinking, creativity, collaboration, communication, learning understanding and empowerment (Stylianidou et al., 2016; Thibaut et al., 2018). Simultaneously, these interdisciplinary STE(A)M activities brought the young students into contact with unprecedented materials and experiences unique to their learning path. Familiarity and contact with mathematical concepts, educational robotics, coding, physics, and materials/tools, methods and applications of engineering worked like an effort to efficient understanding of practical courses (Luehmann, 2009; Sullivan, 2008). The use of project-based and problem-solving framework and the opportunity to participate in authentic STE(A)M learning experiences enhanced motivation for learning through collaborative, experiential and communicative actions (Ministry of Education/P.I., 2021).

Especially, for the learning area of Mathematics during the program and in order to solve the problem of reducing the distance that separates them from their friend who lives in Paris, pre-schoolers had some realistic and unexpected experiences with mathematical concepts and contents cultivating and developing mathematical thinking. They cultivated skills by small or more extensive investigations (work plans, little research, problems to be solved) and cooperative practices (Lavidas et al., 2022). In this way they explored several mathematical concepts like measurement, numbers and operations, algebra and data analysis, patterns, shapes, numbers, lengths and spatial concepts (Larkin & Lowrie, 2023; Lavidas et al., 2022; National Council of Teachers of Mathematics, 2000). Furthermore, the results showed progress in the learning

process through collaborative STE(A)M activities in which students tested various solutions and were led to decisions (Larkin & Lowrie, 2023; Papadakis et al., 2022; Zollman, 2012). They took measurements, calculations, comparisons, correlations, additions and subtractions using conventional and non-standards (arbitrary) units of measurement (Larkin & Lowrie, 2023; Lavidas et al., 2022). Preschool teacher and students cultivated add developed mathematic concepts in their effort to solve the problem of sculpting the natural distances.

In the same way, pre-schoolers used digital materials and tools. Mainly they utilized the possibilities of the robot Bee-Bot by designing paths for moving it to multiple directions giving instructions, directions and orders with the card's commands (Misirli et al., 2019). They tested several directions, they realized their mistakes and failures, and they corrected them. They 'learned' from their mistakes while they had the opportunity to response to high-demand cognitive processes and to became familiar with coding and robot handling skills cultivating computational skills. The use of the Bee-Bot robot excited and actively engaged students, while the multiple trials and directions to bee's movement brought them face to face with their mistakes and the improvement of the ability of problem-solving (Buchter et al., 2017; Clements & Sarama, 2002; Papadakis et al., 2022; Stylianidou et al., 2016; Van der Graaf et al., 2016). As they tested several solutions to solve problem-solving situations students have the opportunity to construct and reflect on new learning trajectories (Misirli et al., 2019).

Regarding the cultivation and familiarization with engineering and construction concepts, young students with the use of digital and conventional tools were led to critical, analytical and synthetic thinking processes kindergarten (Ministry of Education/P.I., 2021). They approached technical knowledge through collaborative actions, exchanging opinions while at the same time cultivating linguistic skills through dialogues, debates, argumentation, etc. Furthermore, the artistic nature of the children by stimulating their imagination and aesthetics worked alongside and simultaneously with the technical knowledge and skills of construction and engineering kindergarten (Ministry of Education/P.I., 2021).

In this context, through these interdisciplinary activities and in a teamwork framework pre-schoolers made choices and decisions, became architects, builders, civil engineers. They cultivated and developed important skills in mechanical and engineering design, distances measurement and calculation, buildings constructions, etc. (Davis et al., 2017; Stylianidou et al., 2016).

Discussion and Conclusion

The project-based STE(A)M activities which are presented in this paper are an example of good practices in introducing preschool students to pioneering and unexplored learning areas, like STE(A)M literacy and education. Although, there is a need for more familiarization and training of preschool teachers with the concepts and materials of STE(A)M education (Buchter et al., 2017; Papadakis et al., 2022; Sullivan et al., 2017). Preschool teachers must be motivated themselves but also engage in innovative actions in their classrooms while at the same time they should activate students' interest by improving teaching practices. As mediators of knowledge (Kucer, 2009) and orchestrators of the learning process (Ministry of Education/P.I., 2021) they have the opportunity to strength and encourage the self-regulation of the learning process for their students.

The experience of this project shows that the implementation of a project-based and a problem-solving process in an early childhood education could be an ideal educational framework for the cultivation of STE(A)M skills, especially mathematical concepts and coding abilities (Papadakis et al., 2022; Van der Graaf et al., 2016).

As STE(A)M education is crucial to meet the needs of a changing world pre-schoolers should have the opportunity to be trained and prepared to bring knowledge and skills to solve problems, to derive meaning and joy from authentic learning experiences, and know how to gather and evaluate evidence to make decisions. As young children are naturally curious about their world (Piaget & Inhelder, 1928) and as STE(A)M literacy is considered

really crucial to students' future success (Fayer, 2017) we propose the extension and expansion of similar good practices. Knowledge and experience of such good practices in early childhood education needs to be expanded to enable the academic and educational community to improve their theoretical approaches and practices (Sullivan et al., 2017). In conclusion, project-based and problem-solving activities are the ideal educational context to support and empower STE(A)M education in early childhood education.

Implications and Limitations

As STE(A)M is important for progress in today's society and global competition these project-based and problem-based instruction STEM activities have provided an innovative context in which many skills and abilities were cultivated in many ways. The limitations of this study are that these activities were implemented in a case-study context. More research evidence is needed for further scientific knowledge and more new perspectives and advances in educational and scientific community and research consist a necessity for early childhood education.

As the use of educational robotics and computational thinking consist a pedagogical method and resource for STEM activities which remains unexplored in preschool education, we recommend more opportunities that should be provided in formal school settings for students to use both creativity and logical thought processes in solving problems. By giving students the tools, they need to solve 21st century problems from a variety of perspectives and using a variety of approaches by integrating skills, future scientists and engineers will fully understand the benefits and importance of STEAM approach as an innovative pedagogical approach in preschool education in the postmodern era.

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Ethics Committee
Permission was given by preschool teacher (the author of this paper) and students' parents prior to the research. Ethical considerations and guidelines concerning the privacy of individuals were carefully taken into account throughout the whole research process. The research protocol conforms to the ethical guidelines of the European Union.

Informed Consent Statement
Informed consent was obtained from all subjects involved in the study.

Data Availability Statement
The data are available after conducting the corresponding author.

Conflicts of Interest
The authors declare no conflict of interest.

References

Bellanca, J., & Brandt, R. (2010). *21st Century Skills: Rethinking How Students Learn.* Solution Tree.

Bequette, J. W., & Bequette, M. B. (2012). A place for art and design education in the STEM conversation. *Art Education, 65*(2), 40-47. https://doi.org/10.1080/00043125.2012.11519167

Bers, M. U., Seddighin, S., & Sullivan, A. (2013). Ready for robotics: Bringing together the T and E of STEM in early childhood teacher education. *Journal of Technology and Teacher Education, 21*(3), 355-377.

Bers, M. U., Strawhacker, A. L., & Vizner, M. (2018). *The design of early childhood makerspaces to support Positive Technological Development: Two case studies*. Library Hi Tech. Advance Online Publication. https://doi.org/10.1108/LHT-06-2017-0112

Bishop-Josef, S., Doster, S., Watson, S., & Taggart, D. A. (2016). *STEM and Early Childhood – When Skills Take Root, Pennsylvania business and the military warn of STEM workforce skills gap; urge greater access to pre-k.* Mission: Readiness, Ready Nation.

Buchter, J., Kuchskar, M., Oh-Young, C., Weglarz-Ward, J., & Gelfer, J. (2017). *Supporting STEM in Early Childhood Education*. Policy Issues in Nevada Education 1-12. Available at: https://digitalscholarship.unlv.edu/co_educ_policy/2

Bybee, R. W. (2010). Advancing STEM education: A 2020 vision. *Technology and Engineering Teacher, 70*, 30-35.

Campbell, C., & Speldewinde, C. (2022). Early Childhood STEM Education for Sustainable Development. *Sustainability, 14*(6), 35-24. http://dx.doi.org/10.3390/su14063524

Clements, D.H. & Sarama, J. (2011). Early childhood mathematics intervention. *Science, 333*, 968–970.

Clements, H. D., & Sarama, J. (2002). The role of technology in early childhood learning. *Teaching Children Mathematics, 8*(6), 340-343.

Clements, H. D., & Sarama, J. (2009). *Early childhood mathematics education research: Learning trajectories for young children*. Routledge.

Davis, M. E., Cunningham, C. M. & Lachapelle, C. P. (2017). They can't spell "engineering" but they can do it: Designing an engineering curriculum for the preschool classroom. *Zero to Three Journal, 37*, 4–11.

Day-Hess, C., & Clements, H. D. (2017). The DREME Network: Research and Interventions in Early Childhood Mathematics. *Advances in child development and behavior, 53*, 1-41. https://doi.org/10.1016/bs.acdb.2017.03.002

Dubosarsky, M., John, M. S., Anggoro, F., Wunnava, S., & Celik, U. (2018). An Innovative STEM Curriculum for Early Childhood Classrooms. In L. English & T. Moore (Eds.) *Early Childhood Engineering Research*. Springer.

Fayer, S., Lacey, A., & Watson, A. (2017, January). *STEM Occupations: Past, Present, and Future*. U.S. Bureau of Labor Statistics. Available at: https://www.bls.gov/spotlight/2017/science-technology-engineering-andmathematics-stem-occupations-past-present-and-future/pdf/science-technology-engineering-andmathematics-stem-occupations-past-present-and-future.pdf

Guzey, S. S., Harwell, M., Moreno, M., Peralta, Y., & Moore, T. J. (2017). The impact of design-based STEM integration curricula on student achievement in engineering, science, and mathematics. *Journal of Science Education and Technology*, 26(2), 207-222. https://doi.org/10.1007/s10956-016-9673-x

Hadzigeorgiou, Y. (2016). *Imaginative thinking in science and science education. In Imaginative Science Education* (pp. 1-31). Springer. https://doi.org/10.1007/978-3-319-29526-8_1

Kelley, T. R., & Knowles, J. G. (2016). A conceptual framework for integrated STEM education. *International Journal of STEM Education, 3*(1), 1-11. https://doi.org/10.1186/s40594-016-0046-z

Komis, V., Romero, M., & Misirli, A. (2017). A scenario-based approach for designing educational robotics activities for co-creative problem solving. In *Advances in Intelligent Systems and Computing* (pp. 158-169). Springer.

Kucer, S.B. (2009). *Dimensions of literacy: a conceptual basis for teaching reading and writing in school settings* (3rd edition). Routledge.

Larkin, K., & Lowrie, T. (2023). Teaching Approaches for STEM Integration in Pre- and Primary School: a Systematic Qualitative Literature Review. *International Journal of Science and Mathematics Education.* https://doi.org/10.1007/s10763-023-10362-1

Lavidas, K., Apostolou, Z. & Papadakis, S. (2022). Challenges and Opportunities of Mathematics in Digital Times: Preschool Teachers' Views. *Education Sciences*, 12, 459. https://doi.org/10.3390/educsci12070459

Lippard, C. N., Lamm, M. H. and Riley, K. L. (2017). Engineering Thinking in Prekindergarten Children: A Systematic Literature Review. *Journal of Engineering Education*, 106(3), 454-474. https://doi.org/10.1002/jee.20174

Luehmann, A. L. (2009). Students' perspectives of a science enrichment programme: out-of-school inquiry as access. *International Journal of Science Education, 31*(13), 1831–1855.

Mayerick, M.K. (2011). How STEM education improves student learning. *Meridian K-12 School Computer Technologies Journal, 14*(1), 1-5.

McClure, E., Guernsey, L., Clements, H.D., Bales, S., Nichols, J., Kendall-Taylor, N. & Levine, M. (2017). Guest Editorial: How to Integrate STEM Into Early Childhood Education. *Science and Children, 055*. https://doi.org/10.2505/4/sc17_055_02_8

Ministry of Education (2003). *A cross thematic curriculum framework for compulsory education for kindergarten*. Athens, Greece: YPEPTH/P.I.

Ministry of Education (2021). *Curriculum of Preschool Education-Kindergarten*. Athens, Greece: YPEPTH/P.I.

Misirli, A., Komis, V., & Ravanis, K. (2019). The construction of spatial awareness in early childhood: the effect of an educational scenario-based programming environment. *Review of Science, Mathematics and ICT Education, 13*(1), 111-124.

National Council of Teachers of Mathematics (2000). *Principles and Standards for School Mathematics*. National Council of Teachers of Mathematics.

O Connell, K. B., Keys, B., & Storksdieck, M. (2017). *Taking Stock of Oregon STEM Hubs: accomplishments and challenges*. Corvallis.

Papadakis, S., Kalogiannakis, M., & Gözüm, A˙IC. (2022). Editorial: STEM, STEAM, computational thinking, and coding: Evidence-based research and practice in children's development. *Frontiers in Psychology*. *13*. 111-476. https://doi.org/10.3389/fpsyg.2022.1110476

Piaget, J. & Inhelder, B. (2000). *The psychology of childhood* (H. Weaver, Trans.). (Original work published 1928). Basic Books.

Salvatierra, L. & Cabello, V.M. (2022). Starting at Home: What Does the Literature Indicate about Parental Involvement in Early Childhood STEM Education? *Education Sciences,12*, 218. https://doi.org/10.3390/educsci12030218

Sousa, D. A., & Pilecki, T. (2013). *From STEAM to STEAM: Using brain-compatible strategies to integrate the arts*. Thousand Oaks.

Stylianidou, F., Glauert, E., Rossis, D., & Havu-Nuutinen, S. (2016). 'Creative Little Scientists' Project: Mapping and Comparative Assessment of Early Years Science Education Policy and Practice. In N. Papadouris, A. Hadjigeorgiou, C. Constantinou (Eds.), Insights from Research in Science Teaching and Learning. Selected Papers from the ESERA 2013 Conference. *Contributions from Science Education Research*, Vol. 2, pp. 201-220. Springer, Cham. https://doi.org/10.1007/978-3-319-20074-3_14

Sullivan, A., & Bers, M. U. (2017). Dancing robots: Integrating art, music, and robotics in Singapore's early childhood centers. *International Journal of Technology and Design Education*. Online First. https://doi.org/10.1007/s10798-017-9397-0

Sullivan, F. R., & Heffernan, J. (2016). Robotic Construction Kits as Computational Manipulatives for Learning in the STEM Disciplines. *Journal of Research on Technology in Education*, *48*(2), 105-128, https://doi.org/10.1080/15391523.2016.1146563

Sullivan, F. R. (2008). Robotics and science literacy: thinking skills, science process skills and systems understanding. *Journal of Research in Science Teaching, 45*(3), 373–394. https://doi.org/10.1002/tea.20238.

Tank, K. M., Moore, T. J., Dorie, B. L., Gajdzik, E., Sanger, M. T., Rynearson, A. M., & Mann, E. F. (2018). Engineering in early elementary classrooms through the integration of high-quality literature, design, and STEM+C content. In L. English and T. Moore, (Eds.), *Early Engineering Learning* (pp. 175-201). Singapore: Springer.

Thibaut, L., Knipprath, H., Dehaene, W., & Depaepe, F. (2018). The influence of teachers' attitudes and school context on instructional practices in integrated STEM education. *Teaching and Teacher Education*, *71*, 190-205. https://doi.org/10.1016/j.tate.2017.12.014

Van der Graaf, J., Segers, E., & Verhoeven, L. (2016). Scientific reasoning in kindergarten: Cognitive factors in experimentation and evidence evaluation. *Learning and Individual Differences*, 49, 190-200. https://doi.org/10.1016/j.lindif.2016.06.006

Wood, E., & Hedges, H. (2016). Curriculum in early childhood education: Critical questions about content, coherence, and control. *The Curriculum Journal*, 27, 387-405. https://doi.org/10.1080/09585176.2015.1129981

Zollman, A. (2012). Learning for STEM literacy: STEM literacy for learning. *School Science and Mathematics*, *112*, 12-19. https://doi.org/10.1111/j.1949-8594.2012.00101.x